FOOD SIZE PREFERENCES OF THE RED COD PSEUDOPHYCIS BACCHUS (TELEOSTEI: MORIDAE)

G. HABIB

*Department of Zoology, University of Canterbury, Christchurch, New Zealand

ABSTRACT

The stomachs of 2 294 red cod *Pseudophycis bacchus* taken from Canterbury waters, New Zealand, between October 1971 and October 1972 were examined: 1 383 contained food. Prey species identified were: 46 fish, 46 crustaceans, 9 molluscs, 3 urochordates, 1 annelid and 1 echinoderm; 12 items were unidentified. Small cod (<250 mm) fed predominantly on small invertebrates, medium cod (250-450 mm) fed on fewer invertebrates and on fishes from 40-100 mm in length, and large cod (>450 mm) took still fewer invertebrates and also fishes from 100-300 mm in length. Invertebrates in the diet of large red cod were the seasonally abundant decapod crustacea *Nectocarcinus antarcticus, Ovalipes punctatus* and *Munida gregaria*.

INTRODUCTION

Food and feeding studies on fishes are concerned with the characterisation and quantification of the diet in relation to habitat and food availability. Information on food size preferences, which may be related to diet changes and increases in size of food items as fish grow, is often found (Steven 1930, Allen 1935, Swynnerton and Worthington 1940, Smith 1947, Dunn 1954, Larsen 1966). Where fish of one species take the same type of food (e.g. another fish), the larger individuals may choose larger individual food organisms (Allen 1939, Reintjes and King 1953, Western 1969, Bulkley 1970). Both types of food preferences were found in red cod *Pseudophycis bacchus* (Forster *in* Bloch and Schneider, 1801).

MATERIALS AND METHODS

Between October 1971 and October 1972, 2 294 red cod were trawled in Canterbury waters (42°33' - 44°55'S, 171°08' - 174°02'E), New Zealand. Soon after capture, they were measured and their stomachs removed and preserved in formalin. In the laboratory, stomach contents were, where possible, identified to species level. Most food items were identifiable by eye but occasionally a binocular microscope was used.

* Present address: Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington, New Zealand.

FISHERIES RESEARCH PUBLICATION NO. 268

Only 1 383 stomachs contained food. The 106 prey species present included 46 fish, 46 crustaceans, 9 molluscs, 3 urochordates, 1 annelid and 1 echinoderm. There were 12 unidentified items (for details of species composition, see Habib 1975: Figs 35-44, Table 34).

To show changes in the diet with growth, each stomach was placed in one of 4 categories according to its contents: invertebrates, invertebrates and fish, fish, and debris and digested matter. For each of the size groups of cod examined (<250 mm, 250-450 mm, >450 mm), the number of stomachs in each category was converted to a percentage of the total number of fish examined.

The lengths of all fish in stomachs were measured, and for seaperch *Helicolenus papillosus* and tarakihi *Cheilodactylus macropterus*, weights were also taken.

RESULTS AND DISCUSSION

The proportions of red cod feeding on invertebrates, fish, or a mixture of these varied with cod size (Table 1). Over 75% of small cod (<250 mm) contained only invertebrates, but only 58% of medium-sized cod (250-450 mm) and 32% of large cod (>450 mm) did so. Conversely, the proportions of cod which took only fish increased with cod size from 5% in small to 20% in medium and to 37% in large cod. Proportions containing both fish and invertebrates also increased with cod size: 3% in small, 12% in medium, and 18% in large cod. Thus the proportion containing some fish increased from 9% to 55%, and the proportion containing some invertebrates fell from 80% to 50% with increasing cod size.

TABLE 1. COMPOSITION OF THE DIET OF THE RED COD IN RELATION TO THEIR SIZE.

Size range of red cod (mm)	Number, (N)	Percentage of red cod containing: Invertebrates	Fish	Invertebrates and fish	Debris and Digested Matter
<250	236	77	6	3	14
250-450	430	58	20	12	10
>450	717	32	37	18	13

With these changes in diet, the size of food items changed from small invertebrates such as *Pontophilus australis* and *P. pilosoides* to larger items such as the sand flounder *Rhombosolea plebeia*.

The change from an invertebrate to a fish diet was not complete largely because of the seasonal occurrence of large quantities of the portunid crabs *Nectocarcinus antarcticus* and *Ovalipes punctatus*, and the galatheid *Munida gregaria*. When these occurred, the stomachs of entire catches of red cod were often full of them (see also Graham 1953: 168-169). Even predators such as barracouta *Thyrsites atun* and the southern kingfish *Rexea solandri* forego their normal fish diet for these seasonally abundant invertebrates (author's personal observation).

Further evidence of increases in prey size as red cod grow comes from length measurements of 13 species of fish found intact in the stomachs. Although there was some overlapping of prey sizes between the size classes of red cod, it is clear that there was a positive relationship between increasing predator and prey size (Table 2, Fig. 1). The high correlation coefficients (r) for the regressions in Figure 1 show the strength of this relationship for two of the prey species.

TABLE 2. SIZE RELATIONSHIP BETWEEN RED COD AND FISH PREY SPECIES FOUND IN THEIR STOMACHS.

Red cod length (mm)	Prey species	Prey length range (mm)
253	*Arnoglossus scapha* (Bloch and Schneider, 1801)	45
254	*Argentina elongata* Hutton, 1879	54
270	*Hemerocoetes waitei* Regan, 1914	75
381	" "	70-100
399	" "	80-100
422	*Pelotretis flavilatus* Waite, 1910	85
436	*Hemerocoetes waitei*	100-150
459	" "	100-150
499	" "	100-150
500	" "	100-150
540	" "	120-190
545	*Cythus novaezelandiae* (Arthur, 1885)	144
579	*Arnoglossus scapha*	150
583	*Rexea solandri* (Cuvier and Valenciennes, 1832)	165
626	*Hemerocoetes waitei*	235
623	*Conger verreauxi* Kaup, 1856	206
634	*Hemerocoetes waitei*	217
645	*Chelidonichthys kumu* (Lesson and Garnot, 1829)	180-220
649	*Thyrsites atun* (Euphrasen, 1791)	170-220
654	*Coelorhynchus australis* (Richardson, 1839)	234
688	*Callorhynchus milii* Bory de St Vincent, 1823	305

This predator-prey size relationship has been found in many fish (e.g. see Dunn 1954), and is explicable in terms of the catchability of prey in relation to changes in habitat, ability and activities of the fish (Smith 1947). As they grow most fish become able to secure larger prey through changes in locomotory apparatus which increase swimming velocity and manoeuvrability, and changes in the relative sizes of prey-securing mechanisms (e.g. the mouth) and the digestive system. Many species may be compelled to do so to obtain sufficient nutrition for their immediate needs and for growth. This is because the amount of food required increases as a fish grows. If it remains on a diet

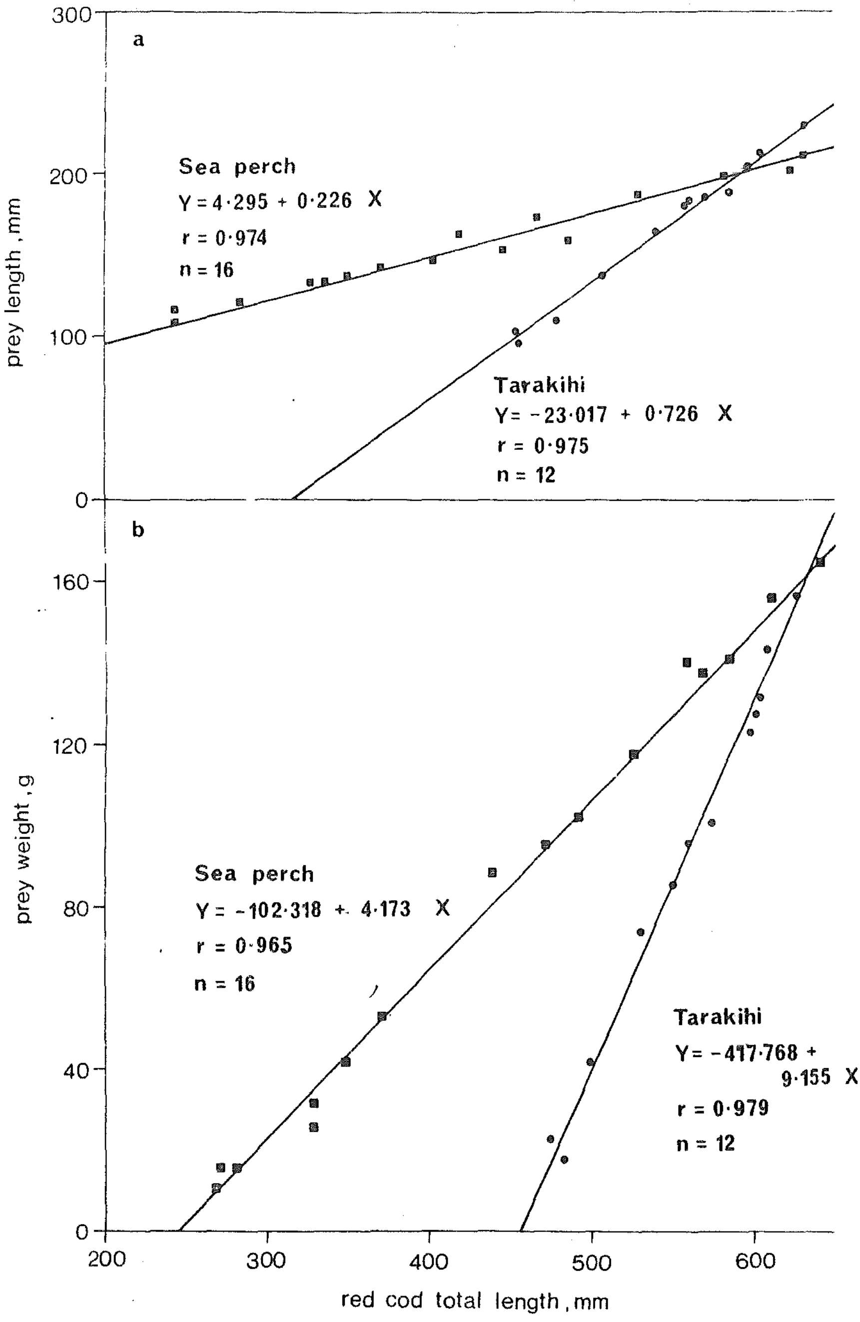

Fig. 1. a. Prey length - red cod length regressions for the prey species seaperch and tarakihi. b. Prey weight - red cod length regressions for the prey species seaperch and tarakihi.

of small food items, it will usually experience increasing difficulty in obtaining enough food. To avoid this, fish change their diet so as to take their food in larger units. This usually results in fewer items being eaten each day although food intake increases. There is a saving in time and effort but this is offset to some extent by the greater difficulty of capture of the less abundant larger prey.

This explanation can probably be applied to the relationship between red cod and their prey except where large quantities of small invertebrates are available. At these times, red cod expend little energy to secure a sufficient number of these small food items for maintenance and growth.

ACKNOWLEDGMENTS

This paper is part of a study undertaken whilst in receipt of a research grant from the New Zealand Ministry of Agriculture and Fisheries to whom I express my thanks. I also thank Professor G.A. Knox and Dr C.L. McLay of the Zoology Department, University of Canterbury, Christchurch, for their supervision.

LITERATURE CITED

ALLEN, K.R. 1935. The food and migration of the perch (*Perca fluviatilis*) in Windermere. *Journal of Animal Ecology 4*: 264-273.

——— 1939. A note on the food of pike (*Esox lucius*) in Windermere. *Journal of Animal Ecology 8*: 72-75.

BULKLEY, R.V. 1970. Feeding interaction between adult bass and their offspring. *Transactions of the American Fisheries Society 99*: 732-738.

DUNN, D.R. 1954. The feeding habits of some of the fishes and some members of the bottom fauna of Llyn Tegid (Bala Lake) Merionethshire.. *Journal of Animal Ecology 23*: 224-233.

GRAHAM, D.H. 1953. *A Treasury of New Zealand Fishes*. A.H. and A.W. Reed, Wellington. 404 pp.

HABIB, G. 1975. Aspects of the biology of the red cod *Pseudophycis bacchus*. Unpublished Ph.D. thesis, Department of Zoology. University of Canterbury, New Zealand. 203 pp.

LARSEN, K. 1966. Studies on the biology of Danish stream fishes. II. The food of pike (*Esox lucius* L.) in trout streams. *Meddelelser fra Danmarks Fiskeri - og Havundersogelser 4*: 271-326.

REINTJES, J.W. and KING, J.E. 1953. Food of yellowfin tuna in the Central Pacific. *U.S. Department of the Interior, Fish and Wildlife Service, Fishery Bulletin 54*: 91-110.

SMITH, M.W. 1947. Food and killifish and white perch in relation to supply. *Journal of the Fisheries Research Board of Canada 7*: 22-33.

STEVEN, G.A. 1930. Bottom fauna and the food of fishes. *Journal of the Marine Biological Association U.K. 16*: 677-701.

SWYNNERTON, G.H. and WORTHINGTON, E.B. 1940. Note on the food of the fish in Haweswater (Westmorland). *Journal of Animal Ecology 9*: 183-187.

WESTERN, J.R.H. 1969. Studies on the diet, feeding mechanism and alimentary trace in two closely related teleosts, the freshwater *Cottus gobio* L. and the marine *Parenophrys bubalis* Euphrasen. *Acta Zoologica 50*: 185-205.